5 TEMPORAL CHANGES IN PARAMETER ESTIMATES FOR 8-DIGIT WATERSHEDS

As each round of statewide sampling by the MBSS (or the Survey) is conducted at regular intervals over time, temporal changes (trends) in the stream condition statewide and for individual 8-digit watersheds can be evaluated. Such monitoring data are necessary to assessing whether implementation of Total Maximum Daily Loadings (TMDLs) and other restoration measures are effective in achieving or maintaining water quality standards (or in effecting other improvements in stream quality). The MBSS also provides information on physical parameters that can be used to track changes in habitat conditions and link such changes to trends in water quality.

This chapter compares results for the first year of MBSS Round Two with data from Round One (1995-1997). Nine of the 8-digit watersheds sampled in 2000 also had more than 10 spring samples in one or two years of MBSS Round One. Data from two or three years are insufficient to estimate trends, but can be used to assess differences. The mean fish and benthic IBI scores were estimated as well as the percentage of stream miles with fish or benthic IBI less than 3 for each year, along with the 90% confidence intervals. The combined IBI was not employed in the inter-annual variability analysis because comparisons could have obscured real differences apparent in individual fish or benthic IBIs. No significant yearly differences in mean fish and benthic IBI scores were observed. In general, the mean IBI scores were stable over time (Table 5-1). The yearly estimated confidence intervals for percentage of stream miles with fish or benthic IBI scores less than 3 overlapped for all watersheds except for the Upper Monocacy which had an interval estimate of 19.9 to 60.8 % for the benthic IBI in 2000 as compared to the 66.6 to 90.5% interval in 1996 (Table 5-2).

The percentage of stream miles with certain chemical and physical habitat characteristics was also estimated. Specifically, the percentages of stream miles with the following were compared:

- Urban land use > 25% of catchment area
- Agricultural land use > 75% of catchment area
- Physical Habitat Index (PHI) < 42 (poor to very poor)
- No riparian buffer

The interval estimates for these parameters were used to "ground truth" results from the two rounds of MBSS. These parameters would generally be subject to minimal changes over a few years, but will be important for tracking long-term changes in stream habitat. In particular, urban and agricultural lands were derived from the same MRLC data and thus should not exhibit significant change. Any observed changes would result from the selection of different random sampling sites, rather than to real differences between years.

In general, the interval estimates for these habitat parameters overlap across years, as would be expected (Table 5-3). Significant differences between years were observed for only two watersheds. For the Patapsco River Lower North Branch, the estimated percentage of stream miles with riparian buffers in 2000 was significantly lower than for 1995. For Little Patuxent River, the estimates of percentage of stream miles with PHI scores < 42 or with no buffer were significantly lower in 2000 as compared to 1997 estimates. These results suggest that the samples in the two years were located in markedly different streams habitats by chance, and are not likely to reflect real changes in habitat between the years. For 90% confidence intervals, the true percentage of stream miles would be outside the interval estimate in 10% of the cases. Thus, when a large number of comparisons are made, as for this report, some false positives are expected.

The physical habitat for the sites sampled influence the fish and benthic communities. Hence, when comparing estimates of percentage of stream miles with IBI < 3 across years, it is important to evaluate whether the samples were collected in similar habitats. On average, simple random sampling results in the number of sites in each habitat class being proportional to the fraction of streams having that habitat. However, any individual selection of sites could, by chance, result in a higher sampling density in one habitat, especially for low sample sizes. For example, the lower estimate of percentage of stream miles with benthic IBI < 3 in Lower Monocacy watershed in 2000 as compared to 1996 could result from the lower proportion of sampling sites with no riparian buffer in 2000, and may not necessarily be a result of real changes in stream condition.

The detection of trends in mean IBI scores statewide, or for individual watersheds requires a time series of data. Although exact statistics can be obtained for $\geq$ 2, a minimum of four or more rounds of samples collected over time is required to obtain meaningful results using the non-parametric Mann-Kendall test for trends (Gilbert 1987,

Hirsch et al. 1982). While it is true that evaluating some fixed sites that are stable in terms of land use and other stressors would provide additional information on year-to-year variabilities across a wide range of conditions, resources were not available for this type of supplemental effort during the 2000 sampling year.

Table 5-1. Variability in mean fish and benthic IBI scores between the 1995-1997 MBSS and the 2000 MBSS. Watersheds shown are those that contained 10 or more sites in the 1995-1997 MBSS.

Watershed	FIBI	Lower 90%	Upper 90%	BIBI	Lower 90%	Upper 90%
Casselman River 1995	3.78	3.18	4.38	4.02	3.45	4.49
Casselman River 1997	3.67	2.94	4.40	3.28	0.55	5.57
Casselman River 2000	2.63	1.94	3.32	3.38	2.72	3.93
Fifteen Mile Creek 1995	2.18	1.78	2.59	3.18	2.84	3.45
Fifteen Mile Creek 2000	3.00	1.95	4.05	3.82	3.51	4.08
Upper Monocacy River 1996	3.05	2.40	3.70	2.12	1.67	2.49
Upper Monocacy River 2000	2.92	2.33	3.51	3.10	2.77	3.37
Brighton Dam 1997	2.86	2.59	3.13	3.53	3.20	3.80
Brighton Dam 2000	3.54	3.25	3.83	3.69	3.27	4.04
Little Patuxent River 1997	2.70	1.87	3.53	2.10	1.69	2.46
Little Patuxent River 2000	3.37	3.05	3.69	2.79	2.32	3.18
South Branch Patapsco 1995	4.23	0.77	7.70	3.43	2.67	4.06
South Branch Patapsco 1996	3.62	2.84	4.39	2.97	2.60	3.28
South Branch Patapsco 2000	3.63	3.28	3.98	3.71	3.33	4.03
Liberty Reservoir 1995	3.94	3.08	4.80	3.55	2.78	4.19
Liberty Reservoir 1996	3.88	2.35	5.41	2.73	1.84	3.48
Liberty Reservoir 2000	3.98	3.84	4.12	3.60	3.37	3.80
Patapsco River Lower North Branch 1995	2.38	1.35	3.42	2.66	2.16	3.08
Patapsco River Lower North Branch 2000	2.64	1.99	3.29	2.84	2.59	3.05
Upper Choptank 1997	3.07	1.40	4.74	2.04	1.34	2.62
Upper Choptank 2000	3.18	2.74	3.62	2.63	2.19	2.99

Table 5-2. Variability in fish and benthic IBI scores between the 1995-1997 MBSS and the 2000 MBSS. Watersheds shown are those that contained 10 or more sites in the 1995-1997 MBSS.

Watershed	Number of Spring Sites	Percentage of stream miles with FIBI < 3	Lower 90% Confidence Limit	Upper 90% Confidence Limit	Percentage of stream miles with BIBI < 3	Lower 90% Confidence Limit	Upper 90% Confidence Limit
Casselman River 1995	11	22.7	3.3	47.0	3.4	0.5	36.4
Casselman River 1997	13	3.9	0.3	30.5	8.4	0.5	32.6
Casselman River 2000	10	60.0	30.4	85.0	30.0	8.7	60.7
Fifteen Mile Creek 1996	20	30.6	14.0	50.8	34.0	17.7	55.8
Fifteen Mile Creek 2000	10	42.9	12.9	61.9	10.0	0.5	39.4
Upper Monocacy 1996	36	29.1	18.2	45.5	80.9	66.6	90.5
Upper Monocacy 2000	18	38.5	16.6	54.5	38.9	19.9	60.8
Brighton Dam 1997	16	54.9	33.3	77.3	17.1	5.3	41.7
Brighton Dam 2000	11	11.1	0.6	42.9	18.2	3.3	47.0
Little Patuxent River 1997	14	62.1	39.0	84.7	86.0	61.5	97.4
Little Patuxent River 2000	13	25.0	17.9	52.7	53.9	28.7	77.6
South Branch Patapsco 1995	11	0.0	0.0	23.9	43.9	20.0	72.9
South Branch Patapsco 1996	18	0.0	0.0	25.3	39.4	8.0	43.9
South Branch Patapsco 2000	10	12.5	0.6	47.1	9.1	0.5	36.4
Liberty Reservoir 1995	19	11.0	1.9	29.6	12.0	4.5	35.9
Liberty Reservoir 1996	18	0.0	0.0	15.3	54.8	34.1	75.6
Liberty Reservoir 2000	16	0.0	0.0	19.3	18.8	5.3	41.7
Patapsco River Lower North Branch 1995	14	39.8	20.6	67.8	66.5	39.0	84.7
Patapsco River Lower North Branch 2000	14	50.0	22.2	77.8	53.3	30.0	75.6
Upper Choptank 1997	14	37.0	15.3	61.0	79.9	53.4	93.9
Upper Choptank 2000	14	30.0	8.7	60.7	57.1	32.5	79.4

Table 5-3. Variability in certain physical and chemical variables between the 1995-1997 MBSS and the 2000 MBSS. Watersheds shown are those that contained 10 or more sites in the 1995-1997 MBSS.

Watershed	Number of Spring Sites	Percentage of Stream Miles with Urban Land > 25%	Lower 90% Confidence Limit	Upper 90% Confidence Limit	Percentage of Stream Miles with Agricultural Land > 25%	Lower 90% Confidence Limit	Upper 90% Confidence Limit	Percentage of Stream Miles with Nitrate Nitrogen > 7 mg/L	Lower 90% Confidence Limit	Upper 90% Confidence Limit	Percentage of Stream Miles with PHI < 42	Lower 90% Confidence Limit	Upper 90% Confidence Limit	Percentage of Stream Miles With No Riparian Buffer	Lower 90% Confidence Limit	Upper 90% Confidence Limit
Casselman River 1995	11.0	0.0	0.0	23.8	0.0	0.0	23.8	0.0	0.0	23.8	49.8	20.0	72.9	22.7	3.3	47.0
Casselman River 1997	13.0	0.0	0.0	20.6	0.0	0.0	20.6	0.0	0.0	20.6	59.8	28.7	77.6	4.2	0.4	31.1
Casselman River 2000	10.0	0.0	0.0	25.9	0.0	0.0	25.9	0.0	0.0	25.9	20.0	3.7	50.7	20.0	3.7	50.7
Fifteen Mile Creek 1996	20.0	0.0	0.0	13.9	0.0	0.0	13.9	0.0	0.0	13.9	93.3	71.7	98.2	13.0	4.2	34.4
Fifteen Mile Creek 2000	10.0	0.0	0.0	25.9	0.0	0.0	25.9	0.0	0.0	25.9	50.0	19.3	80.7	10.0	0.5	39.4
Upper Monocacy 1996	36.0	0.0	0.0	8.0	34.3	20.5	48.3	5.6	1.0	16.5	47.2	32.8	62.1	45.5	30.2	59.4
Upper Monocacy 2000	18.0	0.0	0.0	13.3	28.6	13.2	48.7	5.6	0.3	23.8	56.3	33.3	77.3	16.7	4.7	37.7
Brighton Dam 1997	16.0	0.0	0.0	17.1	36.3	17.8	60.9	17.1	5.3	41.7	17.4	5.4	41.9	17.1	0.0	17.1
Brighton Dam 2000	11.0	0.0	0.0	23.8	45.5	20.0	72.9	0.0	0.0	23.8	9.1	0.5	36.4	0.0	0.0	23.8
Little Patuxent River 1997	14.0	72.0	46.0	89.6	0.0	0.0	19.3	0.0	0.0	19.3	61.9	39.0	84.7	50.0	26.4	73.6
Little Patuxent River 2000	13.0	21.4	6.1	46.6	7.1	0.4	29.7	0.0	0.0	20.6	7.7	0.4	31.6	0.0	0.0	20.6
South Branch Patapsco 1995	11.0	0.0	0.0	23.8	45.6	20.0	72.9	32.8	13.5	65.0	37.2	13.5	65.0	47.4	19.9	72.9
South Branch Patapsco 1996	18.0	0.0	0.0	15.3	60.2	27.3	83.2	0.0	0.0	15.3	22.5	8.2	44.2	37.1	20.0	60.8
South Branch Patapsco 2000	10.0	0.0	0.0	22.1	50.0	24.5	75.5	9.1	0.5	36.4	27.3	7.9	56.4	9.1	0.5	36.4
Liberty Reservoir 1995	19.0	0.0	0.0	14.6	40.5	23.0	63.2	12.4	4.5	35.9	15.7	4.9	36.2	24.4	11.0	47.6
Liberty Reservoir 1996	18.0	0.0	0.0	15.3	52.1	34.1	75.6	16.2	4.7	37.7	21.8	8.0	43.9	39.7	19.9	60.8
Liberty Reservoir 2000	16.0	0.0	0.0	17.1	43.8	22.7	66.7	0.0	0.0	17.1	6.3	0.3	26.4	6.3	0.3	26.4
Patapsco River L N Branch 1995	14.0	84.7	61.5	97.4	0.0	0.0	19.3	0.0	0.0	19.3	39.8	20.6	67.5	48.3	21.6	68.7
Patapsco River L N Branch 2000	14.0	62.5	39.1	82.2	6.3	0.3	26.4	0.0	0.0	18.1	7.7	0.4	31.6	0.0	0.0	18.1
Upper Choptank 1997	14.0	0.0	0.0	19.3	3.0	0.4	29.7	11.2	2.6	38.5	57.7	32.5	79.4	0.0	0.0	19.3
Upper Choptank 2000	14.0	0.0	0.0	19.3	0.0	0.0	23.8	7.1	0.4	29.7	30.8	11.3	57.3	7.1	0.4	29.7

6. SENTINEL SITES

Round Two of the Maryland Biological Stream Survey (MBSS or the Survey) provides an opportunity to examine trends in stream conditions over time. However, to accurately assess temporal trends, it is necessary to differentiate between changes that result from anthropogenic influences and those that result from natural variation. In natural streams, variability in ecological condition between years should be attributable only to variations in precipitation and temperature regimes, as well as to biotic interactions among native species. Therefore, annual monitoring information from minimally disturbed sites (referred to as Sentinel sites) is the best means of interpreting the degree to which changes in biological indicator scores result from natural variability. Understanding the variability of disturbed sites is also important for evaluating status and trends, and can be addressed by monitoring fixed disturbed sites as well. Assuring that stressor conditions do not change at disturbed sites over time is more difficult than for natural sites and the MBSS is not currently sampling such fixed sites. Although there are no longer any pristine streams in Maryland, monitoring a set of the best remaining streams offers a reasonable alternative. In 2000, the Survey began annual sampling at a set of Sentinel sites. The following sections describe the methods used to select Sentinel sites and presents the results of the sampling in 2000.

6.1 METHODS

To ensure that sites with minimal anthropogenic impacts were selected as long-term Sentinel sites, a three tier land use, water quality, and biological community criteria was established and applied to all sites sampled by the MBSS from 1995 to 1999. The following list of Tier 1 criteria was used to identify candidate Sentinel sites:

- No evidence of acid mine drainage in the site catchment
- Sulfate < 50 mg/l
- pH > 6.0 or DOC > 8.0 mg/l (i.e., pH could be < 6 if representing a naturally acidic blackwater stream)
- Nitrate nitrogen < 4.0 mg/l
- Percent forested land use > 50% of catchment area
- Combined Biotic Index (CBI, calculated as the simple mean of FIBI and BIBI scores) > 3.0, or coldwater or blackwater stream

In addition, streams not previously sampled quantitatively by MBSS, but judged to meet the above criteria, were included in the initial pool of candidate sites.

Candidate Sentinel sites were grouped according to stream order and geographic region (Coastal Plain-Eastern Shore, Coastal Plain-Western Shore, Eastern Piedmont, or Highlands) to facilitate representation of small, medium, and large streams throughout Maryland. Subsequently a Tier 2 list of provisional sites was compiled using the following criteria:

- minimum of 5 sites in each geographic region
- minimum of 5 sites in each stream order
- as well as the percentage of forested land use (> 50%)
- the larger amount of the catchment that was located within protected lands (e.g., the Nature Conservancy Preserves and State Forests), and
- sampling site itself was located on public land.

This screening ensured that sites were minimally disturbed and likely to remain so for the foreseeable future.

The provisional Sentinel sites consisted of six or seven sites in each of the four geographic regions that appeared to have the least human disturbance and the least likelihood of changing in the future from human-related activities in their catchments. To make the final Tier 3 selection of Sentinel sites, biologists reviewed information from external sources and conducted site visits (where needed to confirm land use or other watershed conditions).

6.2 RESULTS

Of the nearly 1000 sites sampled by the MBSS in Round One (in 1995-1997), 189 met the criteria for candidate Sentinel sites (15 Coastal Plain-Eastern Shore, 44 Coastal Plain-Western Shore, 16 Eastern Piedmont, and 114 Highlands) (Appendix Table D-1). The list of candidate sites was reduced to 25 final sites (with six or seven sites in each region) by considering stream size, geographic distribution, the percent of forested land use within the catchment, whether or not the site was located on protected lands, and confirmation from a site visit that obvious anthropogenic influences were minimal. Two additional sites on The Nature Conservancy property that had not

previously been sampled by the MBSS were added to this list: one on Nassawango Creek and one on Sideling Hill Creek (to be sampled in 2001). Both streams were added to the list because existing ecological and land use information warranted their inclusion. Appendix Table D-2 provides the final list of 27 Sentinel sites that were sampled during the 2000 sampling season.

Of the 294 sites sampled by the Survey in 2000 (including the 27 Sentinel sites), 91 met the criteria used to identify candidate Sentinel sites (12 in Coastal Plain-Eastern Shore, 20 Coastal Plain-Western Shore, 18 Eastern Piedmont, and 41 Highlands) (Appendix Table D-3). Of the 27 Sentinel sites, 24 continued to meet the minimum Sentinel site criteria. NASS-301-S-2000 was excluded because forested land use did not exceed 50% (42% forested land use). Two additional sites (WCHE-086-S-2000 and WYER-118-S-2000) were excluded because the Combined Biotic Index (CBI) score in 2000 did not exceed 3.0 (and these sites were not coldwater or blackwater streams).

To ensure that adequate numbers of Sentinel sites are available in each geographic region, new sites sampled in 2000 that met the candidate criteria were considered as potential substitutes for the excluded Sentinel sites. Site WCHE-086-S-2000 (Coastal Plain-Western Shore) was replaced with site STMA-104-R-2000. This site is located on Warehouse Run in Saint Mary's County, a stream that has excellent water quality conditions, high biological index scores, and a catchment dominated by forested land use. WYER-118-S-2000 (Coastal Plain-Eastern Shore) was replaced with site CORS-102-R-2000. This site is located on Kirby Creek in Queen Anne's County, a blackwater stream with good water quality and a catchment dominated by forested land use (Appendix Table D-3). Because NASS-301-S-2000 was located on a minimally disturbed, blackwater stream, a replacement site was selected downstream in the watershed so that the percent forested land use would meet the minimum criteria. In future years, other Sentinel sites may be replaced if new anthropogenic impacts are identified.

Although the years in which data were collected at each Sentinel site varied (1995, 1996, 1997, or 2000), values for many of the parameters were not dramatically different between the initial visit and the visit in 2000 (Appendix Table D-4). The most notable changes included variations in blackwater or brook trout designation for a site. For example, UMON-288-S-2000 and JONE-109-S-2000 underwent changes in brook trout designations, based on the presence of brook trout in the sample one year and its absence in the other year.

These changes in designation indicate that it is important to consider other available data in assigning coldwater or blackwater designations. For example, the use of temperature logger records will likely prove a more reliable way to identify coldwater streams than relying on the capture of a single species. (This method may also identify historically coldwater streams from which trout have been extirpated for reasons other than temperature.) In addition, field observations and site-specific knowledge regarding blackwater conditions can augment the strictly water-chemistry based definition, which uses single-point-in-time data that may not account for slight variations in DOC or pH levels.

6.3 DISCUSSION

The existing Sentinel site network contains some of the best freshwater streams in Maryland, (i.e., minimally disturbed and least likely to change in the future from human-related activities) includes first- through third-order streams within each geographic region. However, noticeable differences exist in the quality of streams located in each of the four geographic regions. The Highlands stratum contains seven streams with no apparent anthropogenic impacts. All seven have excellent water quality conditions, good biological index scores, and a catchment dominated by forested land use (76% or greater; Appendix Table D-4). Conversely, it was difficult to identify minimally disturbed sites in the Coastal Plain-Western Shore, Eastern Piedmont, and especially the Coastal Plain-Eastern Shore. Although some sites met the minimum criteria for candidate Sentinel sites, many suffered from significant anthropogenic impacts (mostly resulting from agricultural land use).

The utility of the Sentinel network will depend upon whether land use changes or other potential impacts arise in the Sentinel site catchments. Future sampling will determine whether high quality conditions continue to exist at these locations and they should remain as part of the Sentinel site network. These Sentinel sites will be sampled annually to quantify natural variability. Sentinel sites may be added or replaced in the future to ensure that adequate numbers of undisturbed sites are available to detect trends in site condition. It will likely take several years of data for the Sentinel site network to estimate the temporal variability in the best remaining streams in Maryland.

7. APPLYING THE MARYLAND INTERIM BIOCRITERIA FRAMEWORK TO MBSS 2000 DATA

To meet the requirements of the Clean Water Act, the State of Maryland is in the process of developing biological criteria (biocriteria) for evaluating its waters. As an initial step, the Maryland Department of the Environment (MDE), with the assistance of the Biological Criteria Advisory Committee, has developed an interim framework for the application of biocriteria to the State's water quality inventory (305(b) report) and list of impaired waters (303(d) list). Biological indicators of aquatic condition are the basis of these interim biocriteria.

At present, the proposed biocriteria for wadeable, non-tidal (first- to fourth-order) streams rely on two biological indicators from the MBSS (or Survey), the fish Index of Biotic Integrity (IBI) and the benthic IBI. The interim framework approach is a tool to identify impaired waters at the watershed level using Maryland 8-digit watershed or 12-digit subwatershed designations. In addition to these indices, the Survey provides extensive assessment data on Maryland's non-tidal streams that can aid in identifying stressors or potential sources of degradation. The State is also considering how data from other programs can be used to supplement the MBSS data, thus providing more information for determining watershed impairment status and identifying the sources and causes of impairments.

In this chapter, we describe the results of applying the interim biocriteria framework to MBSS data collected in 2000. This analysis provides a preliminary evaluation of the MBSS data using the interim biocriteria framework. Our analysis is intended to assist the State in preparing the 305(b) report and 303(d) list; however, our results are not final determinations of designated use support.

7.1 METHODS FOR APPLYING BIOCRITERIA

Data from more than 200 sample locations in the watersheds sampled in 2000 were analyzed. Fish and benthic IBI scores served as the bioassessment tools for evaluating sites and watersheds that fail to meet proposed interim biocriteria framework. Ultimately, for locations identified as not achieving the proposed IBI threshold values, follow-up analysis of other biological, water chemistry, physical habitat, and land use data, local knowledge, and field observations should be used to identify likely stressors. The effort is currently beyond the annual scope of the MBSS and is being considered as supplemental monitoring by MDE.

The interim framework proposes two geographic resolutions at which impaired waters would be listed: Maryland 8-digit watersheds and 12-digit subwatersheds. Decision rules currently proposed in the interim biocriteria framework were employed in our analysis, as outlined below. Note that these decision rules have not been formally proposed or accepted by the State and are still being developed.

As discussed in Section 3.1, the following types of sites were not rated:

- If upstream catchment area was < 300 acres, the fish IBI was not rated.
- If brook trout were present and fish IBI would be < 3, the fish IBI was not rated, but conditions were considered satisfactory because brook trout are normally indicators of high quality waters.
- If site was a blackwater stream (defined operationally as dissolved organic carbon (DOC) > 8 mg/l and either pH < 5 or acid neutralizing capacity (ANC) < 200 μeq/l) and fish IBI would be < 3, the fish IBI was not rated.

In addition, prior to application of the biocriteria framework, individual site results were reviewed by MBSS professional biologists (including program managers, QC Officer, and field crew leaders) to ascertain whether any sites should be excluded from this evaluation owing to special sampling circumstances or unusual natural site conditions. Provisions in the interim biocriteria framework recognize that the biocriteria are not applicable under certain conditions and that the use of best professional judgment is appropriate to assess whether particular conditions might result in spurious conclusions. Field data, notes, and site photographs aided in the review session. For any site for which a fish and/or benthic IBI was determined to be not applicable, the site assessment for that IBI was deemed "not rated" and appropriate justification was recorded in the data file.

In addition to the core MBSS sampling within 18 primary sampling units (PSUs including single 8-digit watersheds or combinations of the smallest of these watersheds), results from the Lower Monocacy PSU were analyzed. Lower Monocacy had been previously flagged using Round One data as requiring more data to make a determination of impairment status. Lower Monocacy was re-sampled in

2000 via random site selection and field methods identical to those of the core Survey.

7.1.1 Screening of 8-digit Watersheds

The framework specifies that data from at least 10 sites are needed within an 8-digit watershed in order to evaluate stream status at the 8-digit level. In watersheds with 10 benthic IBI scores but < 10 fish IBI scores, the benthic IBI alone was used for the 8-digit analysis. The number of sites sampled in each watershed was a compromise between the desired precision of estimates and the need for extensive spatial covering, given limited monitoring resources. Even imprecise estimates of condition can be used to target future sampling away from watersheds with good estimates and toward these where greater precision may provide conclusions.

Of the 19 PSUs sampled in 2000, four were "combined watersheds", including more than one 8-digit watershed apiece. These were not assessed at the 8-digit level, because of insufficient sample size within individual 8-digit watersheds. Possible impairments in these areas were to be picked up in 12-digit subwatershed analysis.

Where sufficient data were available within an 8-digit watershed (at least 10 sites with IBI scores), mean IBIs and one-sided 90% confidence interval values were calculated from the data as follows:

$$\text{if } IBI_{mean} \text{ is } < 3,\ CL_{Upper} = IBI_{mean} + (z * SE), \text{ or}$$

$$\text{if } IBI_{mean} \text{ is } \geq 3,\ CL_{Lower} = IBI_{mean} - (z * SE)$$

Where

CL_{Upper} = upper confidence limit

CL_{Lower} = lower confidence limit

z = normal variate (in this case, z = 1.28 for one-sided 90% confidence interval, assuming a normal distribution for mean IBI)

SE = standard error of the mean = $\frac{sd}{\sqrt{n}}$, where sd = standard deviation and

n = number of sites (here, $n \geq 10$)

Following the current guidelines of the interim biocriteria framework, our preliminary analysis applied the following rules to give one of three ratings for 8-digit watersheds:

- **Does not meet criteria:** If the mean and upper bound of the one-sided 90% confidence interval (CL_{Upper}) of either index (FIBI or BIBI) is less than 3.0, the 8-digit watershed is listed as failing to meet the proposed criteria.

- **Meets criteria:** If the mean and lower bound of the one-sided 90% confidence interval (CL_{Lower}) of both indices (FIBI and BIBI) are greater than or equal than 3.0, the 8-digit watershed is listed as meeting the proposed criteria.

- **Inconclusive:** All other cases are inconclusive.

Pending further analysis, watersheds that **do not meet criteria** would be candidates for state reporting as “not supporting aquatic life uses” or “impaired”; watersheds that **meet criteria** would be candidates for reporting as “fully supporting aquatic life uses” or “unimpaired”. Watersheds labeled as **inconclusive** may need further evaluation.

Even within 8-digit watersheds that meet criteria, particular constituent subwatersheds may not. Also, within 8-digit watersheds that are inconclusive, particular 12-digit subwatersheds within them fail to meet criteria. The12-digit subwatershed analysis is described below.

7.1.2 Screening of 12-digit Subwatersheds

Data from individual sites are used to flag 12-digit subwatersheds that may be impaired. One-sided 90% confidence intervals associated with single samples are calculated using an average coefficient of variation (cv) of the IBIs as derived from previous analysis of IBI variability (cv = 0.08; Roth et al. 2001). Confidence intervals around scores for individual samples are calculated as follows:

$$\text{if IBI is } < 3,\ CL_{Upper} = IBI + (z * SE_{EST}), \text{ or}$$

$$\text{if IBI is } \geq 3,\ CL_{Lower} = IBI - (z * SE_{EST})$$

where

CL_{Upper} = upper confidence limit

CL_{Lower} = lower confidence limit

z = normal variate (in this case, z = 1.28 for one-sided 90% confidence interval, assuming a normal distribution for mean IBI)

SE_{EST} = estimated standard error of the mean = IBI x $\frac{cv}{\sqrt{n}}$ (in most cases, n=1)

Following the guidelines of the interim biocriteria framework, our preliminary analysis applied the following rules to give one of three ratings for 12-digit subwatersheds:

- **Does not meet criteria:** If for any site, the value and upper bound of the one-sided 90% confidence interval (CL_{Upper}) of either index (FIBI or BIBI) is less than 3.0, the 12-digit subwatershed is listed as failing to meet the proposed criteria

- **Meets criteria:** If for all sites, the value and lower bound of the one-sided 90% confidence interval (CL_{Lower}) of both indices (FIBI and BIBI) are greater than or equal than 3.0, the 12-digit subwatershed is listed as meeting the proposed criteria.

- **Inconclusive:** All other cases are inconclusive.

Note that this list of site data provides a snapshot of conditions in the sampled segments at one point in time. It does not necessarily reflect conditions throughout a given area. Further investigation may more fully characterize particular stream reaches or watersheds, but this level of effort is beyond the current scope of the MBSS.

7.2 RESULTS OF APPLYING BIOCRITERIA

7.2.1 Provisional Ratings for 8-digit Watersheds

Mean fish IBI, mean benthic IBI, and one-sided confidence intervals for each of the 15 8-digit watersheds sampled in MBSS 2000 (with enough sample sites) are depicted in Figure 7-1. Applying the decision rules above, only the benthic IBI in Upper Choptank watershed had a 90% confidence interval less than 3.0, resulting in an overall status of "fail" for this watershed alone. In all, 3 watersheds passed and 6 were inconclusive (Table 7-1, Figure 7-2). Note that 5 watersheds that originally had 10 or more sites were actually not able to be rated because after site review excluded sites where IBIs were not applicable, the minimum number of sites was not met.

7.2.2 Provisional Ratings for 12-digit Subwatersheds

The PSUs sampled in MBSS 2000 contained 264 12-digit subwatersheds. Excluding the subwatersheds with no sites, the mean number of sites per subwatershed was 1.7. Table 7-2 and Figure 7-3 show preliminary results from the application of the proposed biocriteria framework to these subwatersheds. For clarity of presentation, all 12-digit subwatersheds were compared with the biocriteria, regardless of the status of the 8-digit watershed that contained them. Note that for management purposes, if an impaired 12-digit subwatershed falls within a 8-digit watershed that was already listed as impaired, plans to improve watershed condition would be prepared at the 8-digit level.

Table 7-2 lists all 12-digit subwatersheds grouped by 8-digit watershed; the number of sites per subwatershed that passed, were inconclusive, or failed to meet criteria; and the overall 12-digit status based on the decision rules described above. Of the 264 12-digit subwatersheds,134 were not sampled in MBSS 2000. Of the remaining 130 subwatersheds (regardless of status of the larger 8-digit watersheds), 69 failed, 32 passed, 22 were inconclusive and 7 were not rated because sites were removed during the site review process.

When combined with results of the 8-digit watershed assessments (Table 7-3, Figure 7-4), 9 of the failing subwatersheds fell within failing 8-digit watersheds, and thus would be managed at the 8-digit level. The remaining 60 would be candidates for listing at the 12-digit level. Also, 7 of the 22 inconclusive subwatersheds fell within failing or inconclusive 8-digit watersheds, and would presumably be handled at the 8-digit level.

The majority of failing 12-digit subwatersheds were based on a single failing site. Of the 69 subwatersheds failing, 54 failures were based on one failing site, 13 were based on two failing sites, and 2 were based on 3-5 failing sites. It is important to note that although the State intends to use single-site data as a screening tool to flag subwatersheds (and to avoid missing waters that are impaired), data from a single site do not necessarily represent conditions throughout the subwatershed. Although a single site may not be representative of an entire subwatershed, the State believes it more appropriate to address impairments at the watershed rather than site (segment) level of resolution. Further sampling for stressor identification and/or TMDL development will later define the extent of impairment.

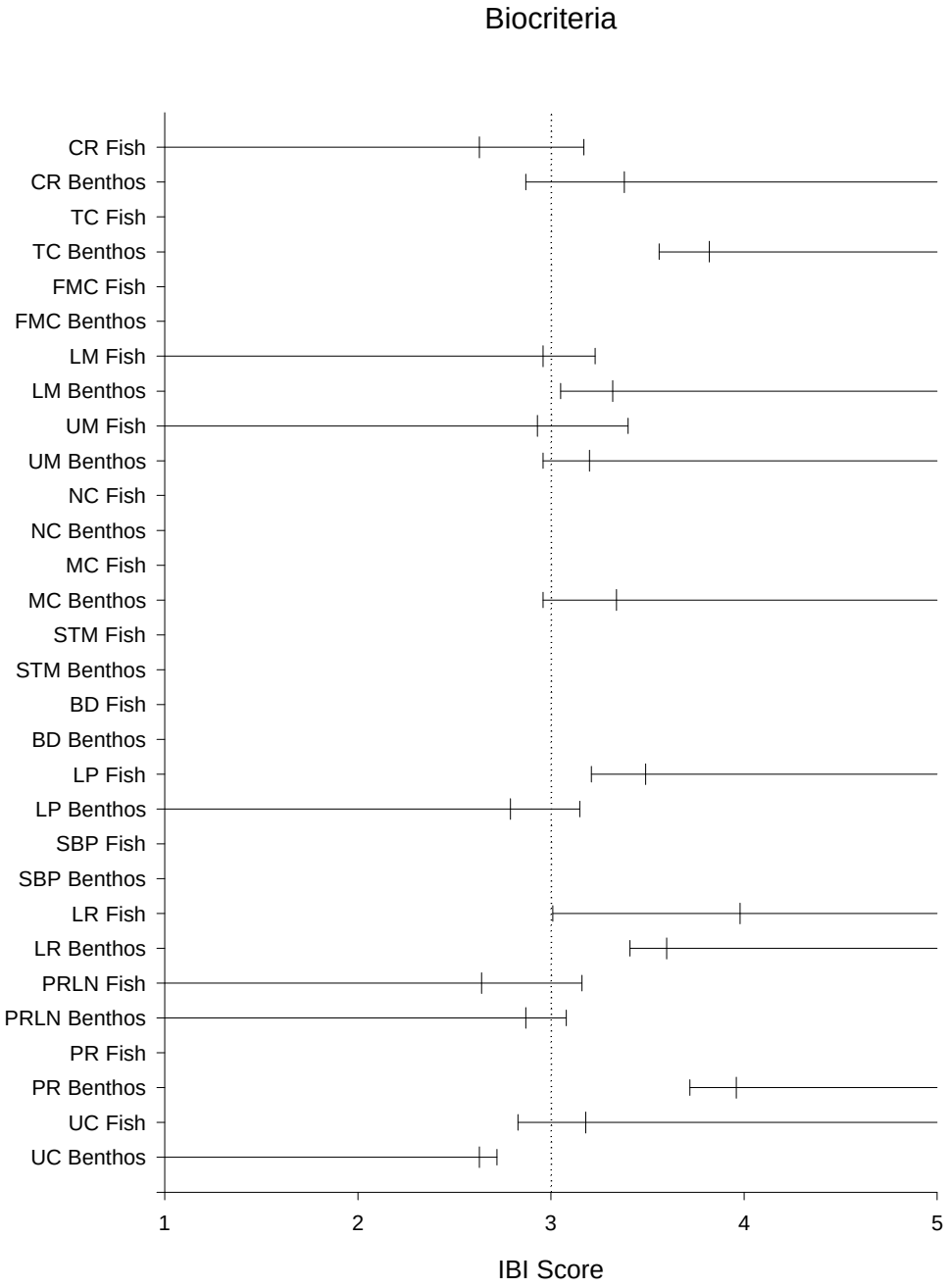

Figure 7-1. Mean fish and benthic IBI scores, with one-sided confidence intervals, for 8-digit watersheds

Abbreviations for watershed names

CR	Casselman River	BD	Brighton Dam
TC	Town Creek	LP	Little Patuxent River
FMC	Fifteen Mile Creek	SBP	South Branch Patapsco
LM	Lower Monocacy River	LR	Liberty Reservoir
UM	Upper Monocacy River	PRLN	Patapsco River Lower North Branch
NC	Nanjemoy Creek	PR	Prettyboy Reservoir
MC	Mattawoman Creek	UC	Upper Choptank
STM	St. Mary's River		

Table 7-1. Provisional ratings of Maryland 8-digit watersheds sampled in the 2000 MBSS based on Maryland's interim biocriteria framework. "Pass" indicates results meet criteria; "fail" indicates results fail to meet criteria.

8 Digit Watershed	Indicator	Mean Indicator Value	Lower Confidence Limit	Upper Confidence Limit	Status	Overall Status
Brighton Dam	Benthos				Not Rated	Not Rated
	Fish				Not Rated	
Casselman River	Benthos	3.38	2.87		Inconclusive	Inconclusive
	Fish	2.63		3.17	Inconclusive	
Fifteen Mile Creek	Benthos				Not Rated	Not Rated
	Fish				Not Rated	
Liberty Reservoir	Benthos	3.60	3.41		Pass	Pass
	Fish	3.98	3.87	3.87	Pass	
Little Patuxent River	Benthos	2.79		3.15	Inconclusive	Inconclusive
	Fish	3.49	3.21		Pass	
Lower Monocacy River	Benthos	3.32	3.05		Pass	Inconclusive
	Fish	2.96		3.23	Inconclusive	
Mattawoman Creek	Benthos	3.34	2.96		Inconclusive	Inconclusive
	Fish				Not Rated	
Nanjemoy Creek	Benthos				Not Rated	Not Rated
	Fish				Not Rated	
Patapsco River Lower North Branch	Benthos	2.87		3.08	Inconclusive	Inconclusive
	Fish	2.64		3.16	Inconclusive	
Prettyboy Reservoir	Benthos	3.96	3.72		Pass	Pass
	Fish				Not Rated	
South Branch Patapsco	Benthos				Not Rated	Not Rated
	Fish				Not Rated	
St. Mary's River	Benthos				Not Rated	Not Rated
	Fish				Not Rated	
Town Creek	Benthos	3.82	3.56		Pass	Pass
	Fish				Not Rated	
Upper Choptank	Benthos	2.38		2.72	Fail	Fail
	Fish	3.18	2.83		Inconclusive	
Upper Monocacy River	Benthos	3.10	2.96		Inconclusive	Inconclusive
	Fish	2.93		3.40	Inconclusive	

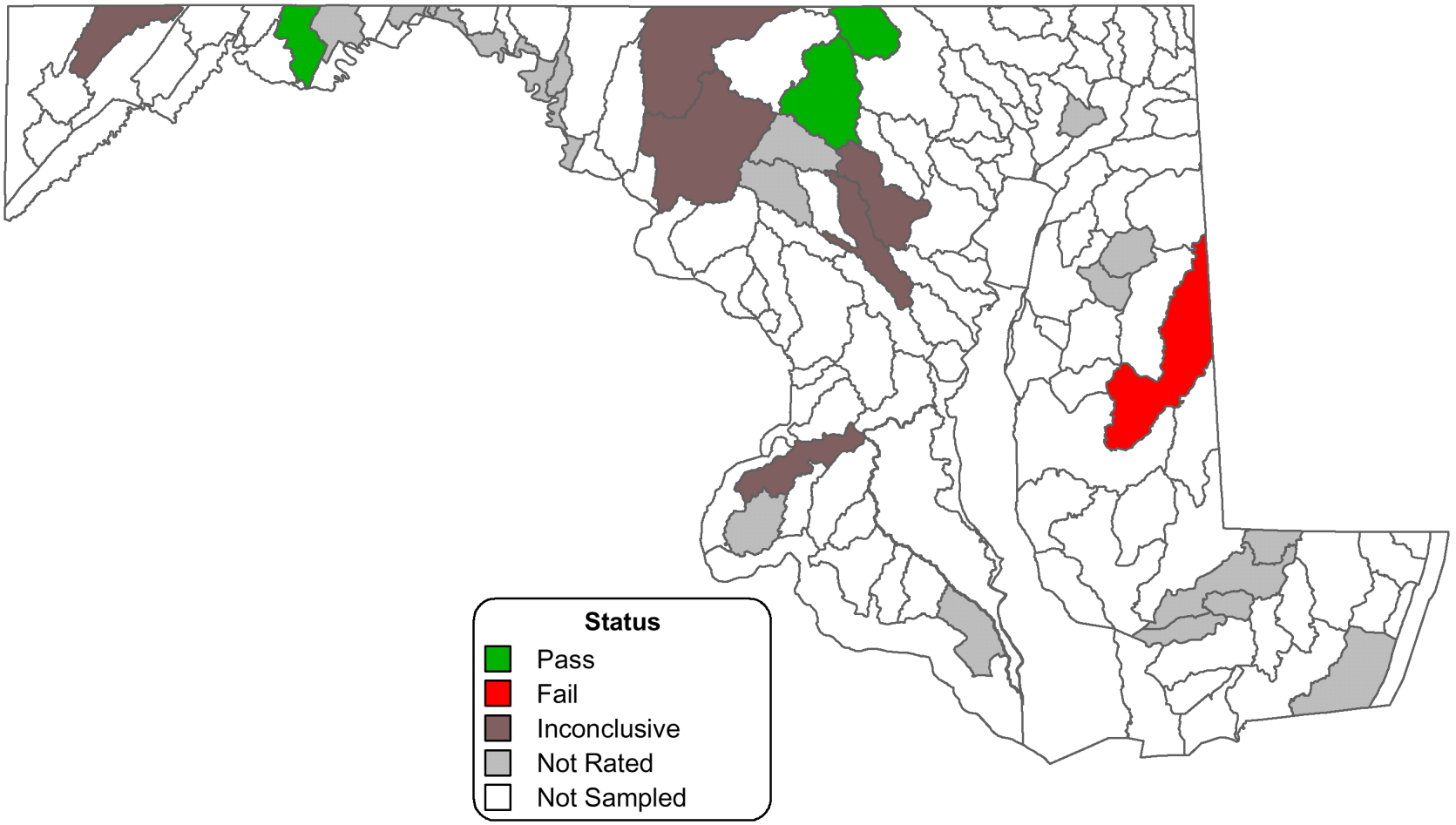

Figure 7-2. Results of applying interim biocriteria framework to assess 8-digit watersheds using MBSS 2000 data

Table 7-2. Provisional ratings of Maryland 12-digit subwatersheds sampled in the 2000 MBSS based on Maryland's interim biocriteria framework

8 Digit Watershed	8 Digit Watershed Status	12 Digit Subwatershed	Number of Sites Pass	Number of Sites Inconclusive	Number of Sites Fail	Number of Sites Not Rated	12 Digit Status
Aberdeen Proving Ground	Not Rated	021307051124					Not Sampled
		021307051125				1	Not Rated
		021307051126	0	0	5	1	Fail
Swan Creek	Not Rated	021301061135	2	1	0	1	Inconclusive
		021301061136					Not Sampled
Brighton Dam	Not Rated	021311080966	2	1	0		Inconclusive
		021311080967	0	0	1		Fail
		021311080968					Not Sampled
		021311080969	4	1	0		Inconclusive
		021311080970	1	1	0		Inconclusive
		021311080971					Not Sampled
		021311080972					Not Sampled
		021311080973					Not Sampled
Casselman River	Inconclusive	050202040030	0	0	2		Fail
		050202040031					Not Sampled
		050202040032	1	0	0		Pass
		050202040033	1	0	1		Fail
		050202040034	1	0	2		Fail
		050202040035					Not Sampled
		050202040036					Not Sampled
		050202040037	1	0	0		Pass
		050202040038	0	0	1		Fail
Corsica River	Not Rated	021305070395				1	Not Rated
		021305070396	1	0	1		Fail
		021305070397	1		1		Fail
Southeast Creek	Not Rated	021305080398					Not Sampled
		021305080399	0	1	2		Fail
		021305080400					Not Sampled
		021305080401	0	1	0		Inconclusive
		021305080402					Not Sampled
		021305080403	1	0	0		Pass
		021305080404					Not Sampled

Table 7-2. (Continued)

8 Digit Watershed	8 Digit Watershed Status	12 Digit Subwatershed	Number of Sites Pass	Number of Sites Inconclusive	Number of Sites Fail	Number of Sites Not Rated	12 Digit Status
Fifteen Mile Creek	Not Rated	021405110134					Not Sampled
		021405110135	3	0	0		Pass
		021405110136					Not Sampled
		021405110137	2	0	0		Pass
		021405110138	3	0	0		Pass
		021405110139					Not Sampled
		021405110140					Not Sampled
		021405110141					Not Sampled
		021405110142	1	0	0		Pass
		021405110143					Not Sampled
		021405110144					Not Sampled
		021405110145					Not Sampled
		021405110146					Not Sampled
		021405110147	1	0	0		Pass
Liberty Reservoir	Pass	021309071046					Not Sampled
		021309071047					Not Sampled
		021309071048	2	3	0		Inconclusive
		021309071049					Not Sampled
		021309071050	4	0	0		Pass
		021309071051					Not Sampled
		021309071052	1	0	0		Pass
		021309071053					Not Sampled
		021309071054					Not Sampled
		021309071055	1	0	0		Pass
		021309071056	2	1	0		Inconclusive
		021309071057					Not Sampled
		021309071058	1	1	0		Inconclusive
		021309071059					Not Sampled
		021309071060					Not Sampled
		021309071061					Not Sampled
		021309071062					Not Sampled

Table 7-2. (Continued)

8 Digit Watershed	8 Digit Watershed Status	12 Digit Subwatershed	Number of Sites Pass	Number of Sites Inconclusive	Number of Sites Fail	Number of Sites Not Rated	12 Digit Status
Little Patuxent River	Inconclusive	021311050946	0	0	1		Fail
		021311050947	0	0	2		Fail
		021311050948	0	0	2		Fail
		021311050949					Not Sampled
		021311050950	0	2	0		Inconclusive
		021311050951					Not Sampled
		021311050952					Not Sampled
		021311050953					Not Sampled
		021311050954	0	1	1		Fail
		021311050955					Not Sampled
		021311050956					Not Sampled
		021311050957	1	2	1		Fail
Lower Monocacy River	Inconclusive	021403020222	1	0	0		Pass
		021403020223	0	1	0		Inconclusive
		021403020224	1	0	1		Fail
		021403020225					Not Sampled
		021403020226					Not Sampled
		021403020227	0	0	1		Fail
		021403020228	1	1	0		Inconclusive
		021403020229	1	0	0		Pass
		021403020230	0	0	1		Fail
		021403020231					Not Sampled
		021403020232					Not Sampled
		021403020233	0	0	2		Fail
		021403020234					Not Sampled
		021403020235	0	1	0		Inconclusive
		021403020236	0	0	1		Fail
		021403020237	0	2	2		Fail
		021403020238	2	0	0		Pass
		021403020239	0	1	1		Fail

Table 7-2. (Continued)

8 Digit Watershed	8 Digit Watershed Status	12 Digit Subwatershed	Number of Sites Pass	Number of Sites Inconclusive	Number of Sites Fail	Number of Sites Not Rated	12 Digit Status
Lower Wicomico	Not Rated	021303010553					Not Sampled
		021303010554					Not Sampled
		021303010555					Not Sampled
		021303010556					Not Sampled
		021303010557					Not Sampled
		021303010558	1	0	1		Fail
		021303010559	0	0	0	1	Not Rated
		021303010560					Not Sampled
		021303010561					Not Sampled
		021303010562	0	0	1		Fail
Monie Bay	Not Rated	021303020544	0	0	0	1	Not Rated
Wicomico Creek	Not Rated	021303030563					Not Sampled
		021303030564					Not Sampled
		021303030565					Not Sampled
Wicomico River Head	Not Rated	021303040566	0	0	1		Fail
		021303040567	0	0	0	1	Not Rated
		021303040568	0	0	1	1	Fail
		021303040569	0	0	1		Fail
		021303040570					Not Sampled
Mattawoman Creek	Inconclusive	021401110780	1	1	0		Inconclusive
		021401110781	0	0	2	1	Fail
		021401110782					Not Sampled
		021401110783	0	0	1		Fail
		021401110784					Not Sampled
		021401110785	2	0	0		Pass
		021401110786	0	1	2		Fail
		021401110787					Not Sampled
		021401110788					Not Sampled
Nanjemoy Creek	Not Rated	021401100775	0	1	0		Inconclusive
		021401100776	0	0	2		Fail
		021401100777	1	0	3		Fail
		021401100778	1	0	0		Pass
		021401100779	1	1	0		Inconclusive

Table 7-2. (Continued)

8 Digit Watershed	8 Digit Watershed Status	12 Digit Subwatershed	Number of Sites Pass	Number of Sites Inconclusive	Number of Sites Fail	Number of Sites Not Rated	12 Digit Status
Patapsco River Lower North Br	Inconclusive	021309061011	0	0	0	1	Not Rated
		021309061012	0	0	1		Fail
		021309061013					Not Sampled
		021309061014	0	2	1		Fail
		021309061015	1	1	1		Fail
		021309061016	0	0	1		Fail
		021309061017	0	1	2		Fail
		021309061018					Not Sampled
		021309061019	1	1	1		Fail
Potomac River Wa County	Not Rated	021405010155	0	0	1		Fail
		021405010156					Not Sampled
		021405010157					Not Sampled
		021405010158	0	0	1		Fail
		021405010159					Not Sampled
		021405010160	1	0	0		Pass
		021405010161					Not Sampled
		021405010162	0	0	1	1	Fail
		021405010163					Not Sampled
		021405010164					Not Sampled
		021405010165	0	0	1		Fail
		021405010166					Not Sampled
		021405010167					Not Sampled
Marsh Run	Not Rated	021405030185	0	0	2		Fail
		021405030186	0	1	0		Inconclusive
Tonoloway	Not Rated	021405070168					Not Sampled
Little Tonoloway	Not Rated	021405090153	0	0	1		Fail
		021405090154	0	2	1		Fail
Prettyboy Reservoir	Pass	021308060313	3	0	1		Fail
		021308060314	2	1	0		Inconclusive
		021308060315	1	0	0		Pass
		021308060316					Not Sampled
		021308060317	1	0	1		Fail

Table 7-2. (Continued)

8 Digit Watershed	8 Digit Watershed Status	12 Digit Subwatershed	Number of Sites Pass	Number of Sites Inconclusive	Number of Sites Fail	Number of Sites Not Rated	12 Digit Status
South Branch Patapsco	Not Rated	021309081020	2	0	0		Pass
		021309081021					Not Sampled
		021309081022	2	1	0		Inconclusive
		021309081023					Not Sampled
		021309081024					Not Sampled
		021309081025	1	0	0		Pass
		021309081026	1	0	0		Pass
		021309081027					Not Sampled
		021309081028	1	0	0		Pass
		021309081029					Not Sampled
		021309081030	1	0	0		Pass
		021309081031	1	0	0		Pass
St. Mary's River	Not Rated	021401030709	0	0	1	1	Fail
		021401030710	1	0	0		Pass
		021401030711					Not Sampled
		021401030712	0	1	0		Inconclusive
		021401030713					Not Sampled
		021401030714	1	0	1		Fail
		021401030715					Not Sampled
		021401030716					Not Sampled
		021401030717	1	0	0		Pass
		021401030718	0	0	1		Fail
		021401030719	0	0	2		Fail

Table 7-2. (Continued)

8 Digit Watershed	8 Digit Watershed Status	12 Digit Subwatershed	Number of Sites Pass	Number of Sites Inconclusive	Number of Sites Fail	Number of Sites Not Rated	12 Digit Status
Town Creek	Not Rated	021405120122	0	0	1		Fail
		021405120123	1	0	1		Fail
		021405120124	0	0	1		Fail
		021405120125					Not Sampled
		021405120126	1	0	0		Pass
		021405120127					Not Sampled
		021405120128	1	0	0		Pass
		021405120129	1	1	0		Inconclusive
		021405120130	1	0	0		Pass
		021405120131	1	0	0		Pass
		021405120132					Not Sampled
		021405120133					Not Sampled
Upper Choptank	Fail	021304040472	0	1	0		Inconclusive
		021304040473					Not Sampled
		021304040474					Not Sampled
		021304040475					Not Sampled
		021304040476					Not Sampled
		021304040477					Not Sampled
		021304040478					Not Sampled
		021304040479					Not Sampled
		021304040480					Not Sampled
		021304040481					Not Sampled
		021304040482					Not Sampled
		021304040483	0	0	1		Fail
		021304040484					Not Sampled
		021304040485	0	0	1		Fail
		021304040486	0	0	1		Fail
		021304040487	1	0	1		Fail
		021304040488					Not Sampled
		021304040489					Not Sampled
		021304040490					Not Sampled
		021304040491					Not Sampled
		021304040492	0	0	0	1	Not Rated

Table 7-2. (Continued)

8 Digit Watershed	8 Digit Watershed Status	12 Digit Subwatershed	Number of Sites Pass	Number of Sites Inconclusive	Number of Sites Fail	Number of Sites Not Rated	12 Digit Status
Upper Choptank (Continued)		021304040493					Not Sampled
		021304040494	1	0	0		Pass
		021304040495					Not Sampled
		021304040496					Not Sampled
		021304040497					Not Sampled
		021304040498					Not Sampled
		021304040499					Not Sampled
		021304040500					Not Sampled
		021304040501					Not Sampled
		021304040502					Not Sampled
		021304040503					Not Sampled
		021304040504					Not Sampled
		021304040505	0	1	1		Fail
		021304040506					Not Sampled
		021304040507					Not Sampled
		021304040508	0	0	1		Fail
		021304040509	0	0	1		Fail
		021304040510					Not Sampled
		021304040511					Not Sampled
		021304040512					Not Sampled
		021304040513					Not Sampled
		021304040514	0	0	1		Fail
		021304040515	0	0	1		Fail

Table 7-2. (Continued)

8 Digit Watershed	8 Digit Watershed Status	12 Digit Subwatershed	Number of Sites Pass	Number of Sites Inconclusive	Number of Sites Fail	Number of Sites Not Rated	12 Digit Status
Upper Monocacy River	Inconclusive	021403030240					Not Sampled
		021403030241					Not Sampled
		021403030242	0	0	1		Fail
		021403030243	0	0	1		Fail
		021403030244	2	1	1		Fail
		021403030245	0	0	1		Fail
		021403030246					Not Sampled
		021403030247	0	1	0		Inconclusive
		021403030249					Not Sampled
		021403030250					Not Sampled
		021403030251	3	1	1	1	Fail
		021403030252					Not Sampled
		021403030253					Not Sampled
		021403030254					Not Sampled
		021403030255					Not Sampled
		021403030256					Not Sampled
		021403030257	0	0	1		Fail
		021403030258	1	0	0		Pass
		021403030259	0	1	1		Fail
		021403030260					Not Sampled
		021403030261					Not Sampled
		021403030262					Not Sampled
		021403030263					Not Sampled
		021403030264					Not Sampled
		021403030265					Not Sampled
		021403030266					Not Sampled
		021403030267					Not Sampled

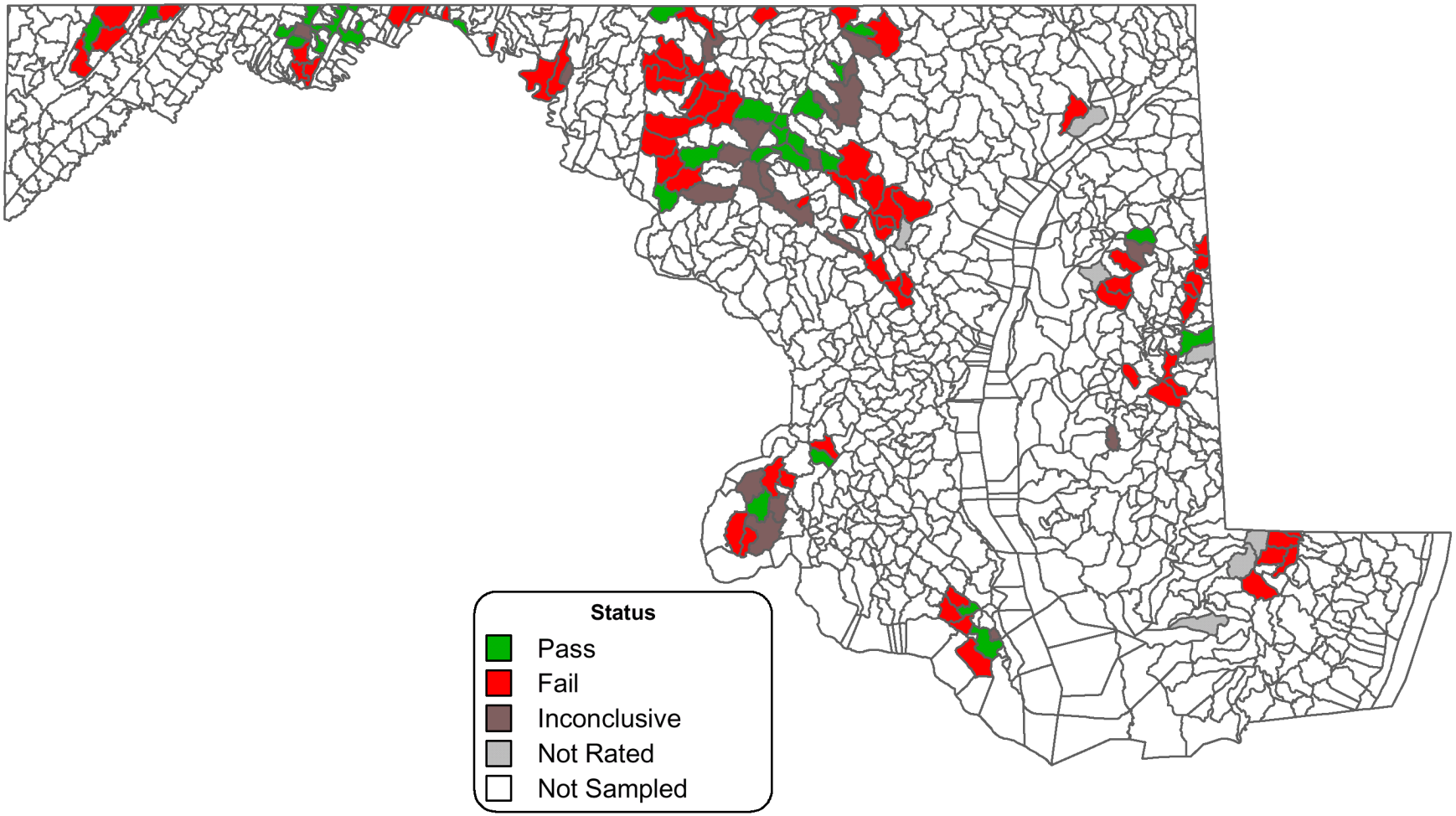

Figure 7-3. Results of applying interim biocriteria to assess 12-digit subwatersheds using MBSS 2000 data

Table 7-3. Summary of 12-digit subwatersheds status ratings, including the number falling within each type of 8-digit watershed					
12-digit Subwatershed Status	**Number of 12-digit Subwatersheds that are within Failing 8-digit Watersheds**	**Number of 12-digit Subwatersheds that are within Passing 8-digit Watersheds**	**Number of 12-digit Subwatersheds that are within Inconclusive 8-digit Watersheds**	**Number of 12-digit Subwatersheds that are within Unrated 8-digit Watersheds**	**Total Number of 12-digit Subwatersheds**
Fail	9	2	32	26	**69**
Pass	1	4	7	20	**32**
Inconclusive	1	4	6	11	**22**
Not Rated	1	0	1	5	**7**
Total Sampled					**130**
Not Sampled					**134**
Total					**264**

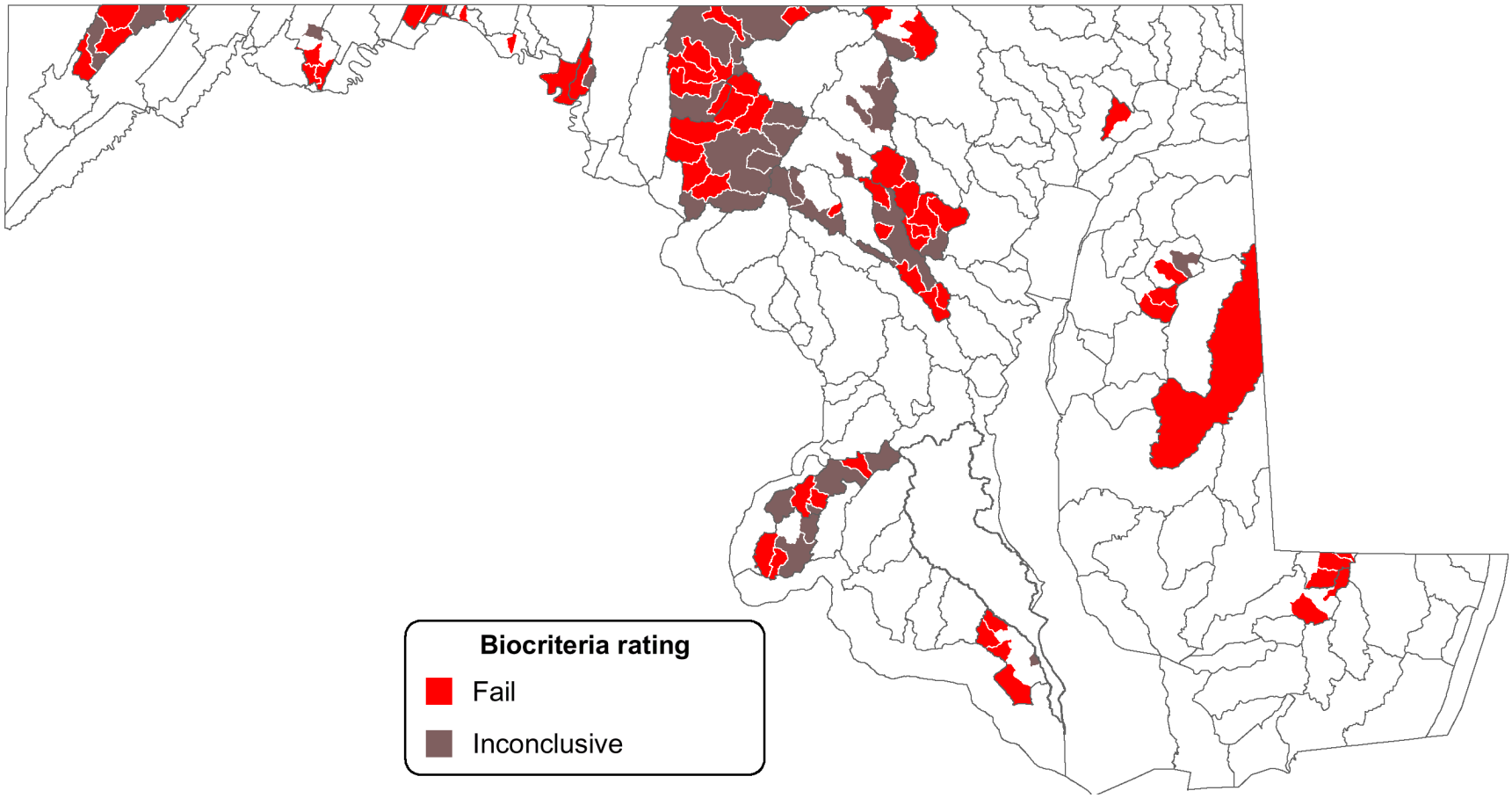

Figure 7-4. Combined set of 8-digit and 12-digit watersheds designated as failing or inconclusive, when interim biocriteria framework was applied to MBSS 2000 data.

The range of possible extent can also be estimated from MBSS data, because the simple random sampling design does support estimation (with known confidence) of the extent of streams having a particular characteristic of interest. For example, we can estimate the percentage of stream miles in a subwatershed that would fail to meet biocriteria, and we can know the exact confidence interval around that estimate, even with small sample sizes. Figure 7-5 illustrates examples of the exact 90% confidence intervals for small samples, for varying numbers of sites sampled (n = 1 to 10), given that all samples have the same outcome. Figure 7-6 shows examples of exact 90% confidence intervals for small samples, given that an outcome occurs in 50% of the samples (e.g., 1 out of 2, 4 out of 8). These confidence intervals are not only applicable to stream data, but are in fact based on the binomial distribution, which would apply to any case with two possible outcomes such as pass/fail.

To evaluate the extent of stream miles failing, 90% confidence intervals were estimated for "percentage of stream miles that fail" in each of the 12-digit watersheds flagged as failing (Table 7-4). Because of the large number of 12-digit subwatersheds that fail to meet criteria, this information could be used to help establish priorities for where managers should target effort in developing remediation strategies. The MDE Biological Criteria Advisory Committee is in the process of examining this and other related recommendations.

Table 7-4. Estimated percentage of stream miles failing, with upper and lower 90% confidence limits (CL), for Maryland 12 digit subwatersheds that rate as "failing" under interim biocriteria framework

8 Digit Watershed	8 Digit Watershed Status	12 Digit Subwatershed	Percentage of Stream Miles that Fail	Lower 90% CL	Upper 90% CL
Aberdeen Proving Ground	Not Rated	021307051126	83.33	41.82	99.15
Brighton Dam	Not Rated	021311080967	100	5	100
Casselman River	Inconclusive	050202040030	100	22.36	100
		050202040033	50	2.53	97.47
		050202040034	66.67	13.54	98.3
		050202040038	100	5	100
Corisca River	Not Rated	021305070396	50	2.53	97.47
		021305070397	50	2.53	97.47
Southeast Creek	Not Rated	021305080399	66.67	13.54	98.3
Little Patuxent River	Inconclusive	021311050946	100	5	100
		021311050947	100	22.36	100
		021311050948	100	22.36	100
		021311050954	50	2.53	97.47
		021311050957	50	9.76	90.24
Lower Monocacy River	Inconclusive	021403020224	50	2.53	97.47
		021403020227	100	5	100
		021403020230	100	5	100
		021403020233	100	22.36	100
		021403020236	100	5	100
		021403020237	50	9.76	90.24
		021403020239	50	2.53	97.47
Lower Wicomico River	Not Rated	021303010558	50	2.53	97.47
		021303010562	100	5	100
Wicomico River Head	Not Rated	021303040566	100	5	100
		021303040568	50	2.53	97.47
		021303040569	100	5	100
Mattawoman Creek	Inconclusive	021401110781	66.67	13.54	98.3
		021401110783	100	5	100
		021401110786	66.67	13.54	98.3
Nanjemoy Creek	Not Rated	021401100776	100	22.53	100
		021401100777	75	24.59	98.73

Table 7-4. (Continued)

8 Digit Watershed	8 Digit Watershed Status	12 Digit Subwatershed	Percentage of Stream Miles that Fail	Lower 90% CL	Upper 90% CL
Patapasco River Lower North Br	Inconclusive	021309061012	100	5	100
		021309061014	33.33	1.7	86.46
		021309061015	33.33	1.7	86.46
		021309061016	100	5	100
		021309061017	66.67	13.54	98.3
		021309061019	33.33	1.7	86.46
Potomac River Wa County	Not Rated	021405010155	100	5	100
		021405010158	100	5	100
		021405010162	50	2.53	97.47
		021405010165	100	5	100
Marsh Run	Not Rated	021405030185	100	22.36	100
Little Tonoloway	Not Rated	021405090153	100	5	100
		021405090154	33.33	1.7	86.46
Prettyboy Reservoir	Pass	021308060313	25	1.27	75.14
		021308060317	50	2.53	97.47
St. Mary's River	Not Rated	021401030709	50	2.53	97.47
		021401030714	50	2.53	97.47
		021401030718	100	5	100
		021401030719	100	22.36	100
Town Creek	Not Rated	021405120122	100	5	100
		021405120123	50	2.53	97.47
		021405120124	100	5	100
Upper Choptank	Fail	021304040483	100	5	100
		021304040485	100	5	100
		021304040486	100	5	100
		021304040487	50	2.53	97.47
		021304040505	50	2.53	97.47
		021304040508	100	5	100
		021304040509	100	5	100
		021304040514	100	5	100
		021304040515	100	5	100

Table 7-4. (Continued)

8 Digit Watershed	8 Digit Watershed Status	12 Digit Subwatershed	Percentage of Stream Miles that Fail	Lower 90% CL	Upper 90% CL
Upper Monocacy River	Inconclusive	021403030242	100	5	100
		021403030243	100	5	100
		021403030244	25	1.27	75.14
		021403030245	100	5	100
		021403030251	16.67	8.5	58.18
		021403030257	100	5	100
		021403030259	50	2.53	97.47

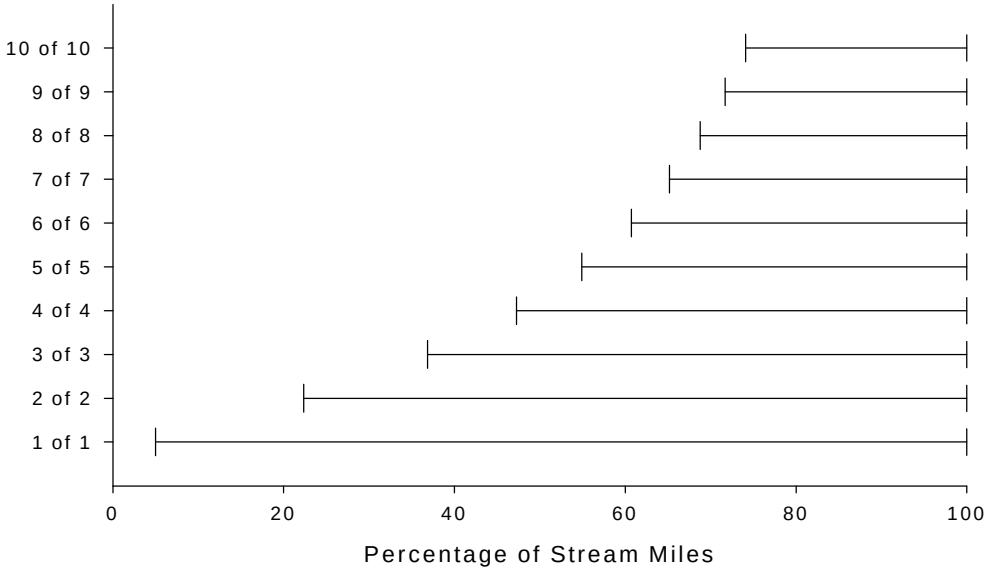

Figure 7-5. Examples of two-sided 90% confidence intervals for the percentage of stream miles with a given characteristic of interest. Numbers on y-axis represent the number of samples with the characteristic, out of a total number of simple random samples.

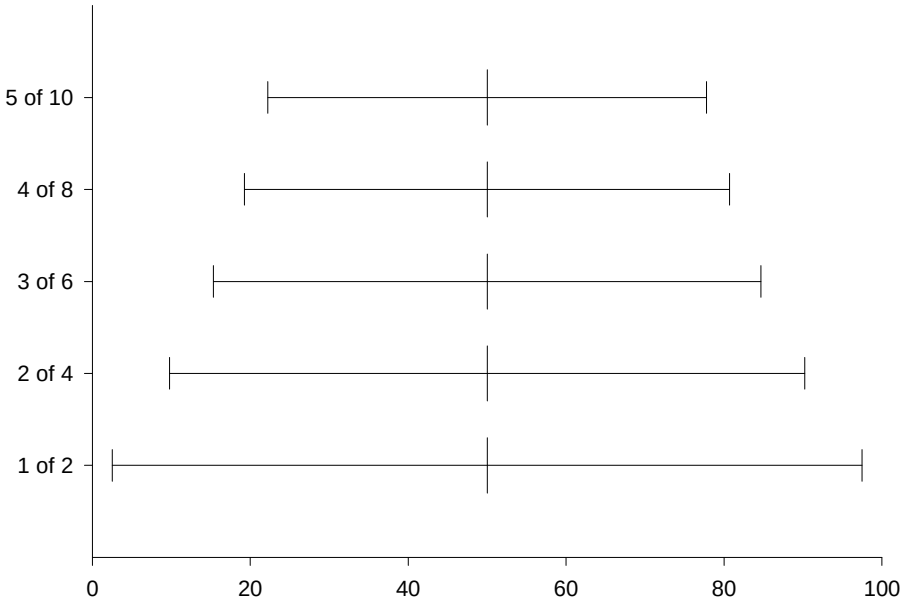

Figure 7-6. Examples of two-sided 90% confidence intervals for the percentage of stream miles with a given characteristic of interest. Numbers on y-axis represent the number of samples with the characteristic, out of a total number of simple random samples.

8 MANAGEMENT IMPLICATIONS AND FUTURE DIRECTIONS

The goal of the Maryland Biological Stream Survey (MBSS or Survey) is to provide natural resource managers, policymakers, and the public with the information they need to make effective natural resource decisions about the State's non-tidal streams and the watersheds they drain. For this reason, the Survey was designed to answer a set of 64 management questions. In the Round One report (Roth et al. 1999), many of these questions were answered, while some remained unanswered and new questions were raised. Many of the answers were the first scientifically defensible and management-relevant answers obtained for these questions.

By the end of Round One, it was apparent that certain management concerns had changed and programmatic needs were evolving. The changes instituted in Round Two were designed to address this changing management context. This chapter focuses on the management implications of the results obtained in 2000, recognizing that this sampling year is only one of five and that many questions will only be answered after Round Two is completed. In addition to implications of the core survey results, this chapter discusses the future sampling and monitoring/assessment activities planned for Round Two and beyond.

8.1 MANAGEMENT IMPLICATIONS

Information from Round One of the Survey is being heavily used to support management and policy initiatives at DNR. Results from sampling in 2000 and future years will be used to help refine answers to the MBSS questions and to address new issues that arise. In addition to serving DNR's program needs, a number of other agencies and institutions have an interest in the Survey's answers to its primary objectives:

- assess the current status of biological resources in Maryland's non-tidal streams;
- quantify the extent to which acidic deposition has affected or may be affecting biological resources in the state;
- examine which other water chemistry, physical habitat, and land use factors are important in explaining the current status of biological resources in streams;
- provide a statewide inventory of stream biota;
- establish a benchmark for long-term monitoring of trends in these biological resources; and
- target future local-scale assessments and mitigation measures needed to restore degraded biological resources.

The information being obtained by the Survey is expected to be highly useful for the new stream corridor goals of the Chesapeake Bay Program. The Chesapeake 2000 Agreement (signed by Virginia, Maryland, Pennsylvania, District of Columbia, U.S. EPA, and Chesapeake Bay Commission) newly recognizes "the need to focus on the individuality of each river, stream and creek" to meet the goal—"Preserve, protect and restore those habitats and natural areas that are vital to the survival and diversity of the living resources of the Bay and its rivers." Specifically, the Agreement commits to the following watershed-based actions:

- Develop and implement watershed management plans in two-thirds of the Bay watershed
- Develop guidelines to ensure the aquatic health of stream corridors
- Select pilot projects that promote stream corridor protection and restoration
- Make available information concerning the aquatic health of stream corridors
- Develop stream corridor restoration goals based on local watershed management planning

Results from the 2000 sampling, as well as future years, will be used to support these actions, just as Round One results were provided to the State's Tributary Strategies program to address the nutrient reduction goals.

The stream corridor information provided by the Survey will also prove invaluable for statewide programs such as the riparian buffer restoration and Greenprint initiatives. As part of the Chesapeake Bay wide goal of restoring 2,010 miles of riparian buffers in the Chesapeake Bay watershed by the year 2010, Maryland has committed to restoring 600 miles of riparian vegetation along its stream corridors. MBSS ground verification of remotely sensed riparian areas can be used, along with data on ecological stream condition,

to determine where restoration will provide the greatest restoration benefit. In a separate initiative, Maryland has designated substantial funding to purchase Greenprint lands that will contribute to an interconnected green infrastructure across the state. Stream corridors are an important part of the contiguous forest and wetland habitats that make up the green infrastructure (linked hubs and corridors worthy of preservation or restoration). MBSS data on the condition of constituent streams will help assign priorities for the purchase of Greenprint lands.

The results of Round Two will continue to support Maryland's participation in the federal Clean Water Action Plan. Round One MBSS data were an essential component of the first Unified Watershed Assessment prepared under this Plan; specifically, DNR incorporated mean values by Maryland 8-digit watersheds for both the fish IBI and benthic IBI. These indicators provided some of the best information provided to U.S. EPA by any state. These IBIs were used with other indicators to help designate both Category 1 (priorities for restoration) and Category 3 (priorities for protection) watersheds within Maryland. Restoration strategies have been developed for many of these priority watersheds, and 2000 sampling results will be used to help implement them (e.g., in Little Patuxent River watershed). Because the design of Round Two focuses on the finer geographic scale of Maryland 8-digit watersheds, future Unified Watershed Assessments will be more complete. Characterization at the 12-digit Maryland watershed scale will be possible for many areas using core MBSS results augmented by county and volunteer monitoring.

In addition to supporting these targeting initiatives, the identification of degraded stream segments has implications for comprehensive protection under the Clean Water Act. Section 101 of the Act states that physical, chemical, and biological integrity of waters should be maintained. Stream segments that fail to do this can be designated as degraded and not attaining designated uses as part of their water quality standards. The Maryland Department of the Environment (MDE) implements the water quality standards program and prepares a 303(d) list of streams not meeting their designated uses. U.S. EPA is encouraging Maryland and other states to use biological criteria (biocriteria) to meet negotiated agreements for expanding their 303(d) lists. Streams rated as poor or very poor by MBSS data are candidates for inclusion on the 303(d) list. Ultimately, total maximum daily loads (TMDLs) must be developed for streams on this list.

Using Round One MBSS data, MDE developed an interim biocriteria framework for Maryland that incorporates stream ratings based on fish and benthic IBIs developed by the urvey (Roth et al. 2000, Stribling et al. 1998) to identify 8-digit watersheds and 12-digit subwatersheds that are impaired. Results from MBSS 2000 will be incorporated with other data to prepare the State's Clean Water Act 303(d) list and biennial 305(b) water quality report. The result of our initial application of the interim biocriteria framework to the MBSS 2000 data indicate that one of the 19 8-digit watersheds sampled and a number of 12-digit subwatersheds are candidates for the 303(d) list (see Chapter 7).

Another important use of MBSS biological data for the water quality standards program is refinement of aquatic life use designations. Each water body in Maryland has an associated designated use that (along with appropriate physical, chemical, and biological criteria) make up the water quality standard for that water body. While some streams have a special use, such as a reproducing trout stream, most have the same general aquatic life use. This general use designation does not capture the natural variability of Maryland streams and therefore does not extend any special protection to streams with unusual diversity or ecological value. U.S. EPA is encouraging states to refine their aquatic life uses into categories with more precise biocriteria. Data from the Survey will be critical to refining aquatic life use designations in this way.

The information on biological diversity collected by the MBSS exceeds that needed to designate the ecological condition of individual watersheds. The extensive geographic reach and quantitative sampling results of the Survey provide an unusual opportunity for evaluating the distribution and abundance of species previously designated as rare only by anecdotal evidence. In 2000 alone, the endemic checkered sculpin and several other species were collected in previously unreported locations. Based on the information gathered in Round One, Maryland DNR's Heritage and Biodiversity Programs are reevaluating state designations of rare, threatened, and endangered species. These reevaluations, as well as MBSS data on unique combinations of species at the ecosystem and landscape levels, will provide critical new information to support biodiversity conservation in the state.

8.2 FUTURE DIRECTIONS

At the end of Round One, it was discovered that most of the original 64 MBSS questions that could not yet be answered dealt with identifying potential stressors using data not collected as part of the Survey. Much of this information will be gathered from other sources and linked to MBSS sites so that statewide estimates can be made of stressor

extent (e.g., number of stream miles with point sources of contamination, amounts of pesticides applied by geographic area, or pattern of landscape patches in upstream catchments). The other issues of original and new interest dealt in large part with the need for finer geographic resolution. As described above, the Round Two design (including adoption of the new 1:100,000-scale stream network, focus on Maryland 8-digit watersheds, and volunteer monitoring at the 12-digit subwatershed scale) will begin to provide this improved resolution. Issues that require continued scrutiny in future years include the following:

- Extending the Survey into tidal streams
- Delineating more stream types requiring new indicators (e.g., coldwater and blackwater streams)
- Refining existing indicators (e.g., physical habitat) and developing new ones (e.g., streamside salamanders in small streams)
- Better characterization of existing and new stressors (e.g., estimating the contribution of eroded soil to sediment loading)
- Improving identification of rare species habitats and other biodiversity components
- Comparing among sample rounds for the detection of trends
- More coordination with counties for greater sample density or cost savings in areas of shared interest

Round Two is capturing considerably more small streams and a few more larger streams than in Round One. This increased efforts provides nearly comprehensive coverage of the stream resources in Maryland. The principal remaining gap is tidal streams, those not covered by tidewater monitoring at DNR. The Round Two design includes a component dedicated to tidal stream sampling that has not yet been implemented because of lack of funding. Specifically, the Round Two design includes pilot sampling of tidal streams that follows the lattice design used for non-tidal streams and includes the same subset of 84 watersheds for sampling each year. A random sample of 20 sites would be selected within each watershed containing tidal streams, and the number of sites allocated to each watershed would be proportional to their tidal stream length.

Analysis of Round One data revealed that Maryland contains substantial miles of streams that are ecologically distinct in terms of natural fish communities. Three kinds of streams were identified where the existing fish IBI is not an effective indicator of stream condition: (1) small streams draining catchments of less than 300 acres, (2) coldwater streams characterized by lower temperatures and prevalence of trout species, and (3) blackwater streams characterized by low pH and high organic content. Temperature loggers were deployed at nearly all randomly selected stream sites in 2000 (and will continue to be deployed throughout Round Two) to improve our ability to identify coldwater streams. Round Two also includes ancillary sampling of coldwater and blackwater streams (which occur in too low proportions of total streams to be captured adequately by the core survey) that will be used to support development of appropriate fish IBIs for these streams. In 2000, 15 coldwater sites were sampled in both stressed and healthy coldwater streams; additional sampling of blackwater streams is planned for future years. The Survey is cooperating with the U.S. Geological Survey to study the feasibility of using streamside salamander sampling in small MBSS streams to develop a second vertebrate indicator for this stream type.

In Round One, a provisional indicator of physical habitat quality, the Physical Habitat Index (PHI), was developed from the quantitative and qualitative data collected in 1995-1997. The approach focused on including only those parameters that were significantly correlated with biological characteristics of interest. The Survey will revisit its approach for assessing stream physical habitat quality in 2001 by reanalyzing all existing physical habitat data.

Effective characterization of stressors will continue to be an important part of the Survey. In many cases, accurate diagnosis of site-specific problems is beyond the capabilities of the Survey and follow-up monitoring is required. This will be the case in most watersheds highlighted for possible inclusion on the state's 303d list of impaired waters. Only when specific causes of degradation are identified and quantified can TMDLs be developed. Nonetheless, the Survey will continue to investigate new analyses of stressor data and produce estimates of the extent and severity of problems to help in natural resource management decision making. In 2000, new information was gathered on riparian buffer, exotic plants, channelization, bar formation, and bank erosion. The total area of eroding banks was reported as an indicator of the amount of sediment being contributed downstream by each watershed. In future years, statistics on these and other stressors will be developed.

As Round Two continues to sample new streams throughout the state, we expect that new location records for many species will be reported. As these records accumulate, the Survey will make them available to the Maryland DNR Heritage and Biodiversity Programs for future listing reevaluations and management planning. The Survey will also conduct more analysis on unique combinations of

species at the ecosystem and landscape levels. Specifically, biodiversity maps based on Round One MBSS data and rare, threatened, and endangered species data will be augmented with Round Two data and GAP analysis data developed by the Heritage and Biodiversity Programs and U.S. Fish and Wildlife Service.

At present, little work has been done to prepare species-specific management plans for unique or at-risk aquatic species. Because the Survey collects information that can be used to identify stressors within a watershed, MBSS data can serve as a logical starting point for developing restoration and protection strategies. Given that the Survey has produced abundance estimates for rare and unique fishes, prioritization of management plan development can be based on population size and known threats.

One of the most important benefits of collecting Round Two data will be the ability of the Survey to compare results over time and detect trends in natural variability, environmental degradation, and restoration success. The sampling in 2000 provides the first opportunity to compare stream condition in selected watersheds across the two rounds. Future sampling years will provide more opportunities and, once Round Two is completed in 2004, rigorous statewide estimates with ample sample density will be used to investigate trends. The interpretation of trends requires that natural temporal change be characterized and understood. To this end, Round Two will continue to annually monitor 25 sentinel sites selected and sampled in 2000. These sites represent the best stream conditions in the state and focus on those areas least likely to change through anthropogenic impact (e.g., in state-managed or protected areas). As Round Two progresses, data from annual sampling of sentinel sites will be analyzed for natural temporal variability.

Recognizing that the core and ancillary sampling by Maryland DNR will never be able to attain the sample density needed for all management decisions in the state, the Survey is focusing on coordination with other monitoring programs (usually county governments) during Round Two. During 2000, comparability analyses were conducted with the biological sampling program of Montgomery County with funding from U.S. EPA. Differences in sample frame, survey design, sampling methods, indicator construction, and reporting were investigated and procedures for combining the results of the two programs were developed. A methods comparison study for benthic sampling and analysis is planned for future years. The Survey is also considering developing guidance for counties in benthic taxonomy, as well as data base standards for sharing of information. To the extent possible, sampling results (e.g., fish IBIs) will be integrated into combined estimates for public reporting in 2000. The Survey will continue coordination with Montgomery, Prince George's, Howard, Carroll, Baltimore and other counties plus Baltimore City, in future years to ensure that programs obtain either greater sample densities or cost savings (from sharing sample sites) for monitoring Maryland streams. The Maryland Water Monitoring Council (MWMC) will play an active role in encouraging these collaborations between state and local agencies.

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